INDOOR AIR QUALITY ASSESSMENT

South Elementary School
719 South Franklin Street
Holbrook, MA 02343

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health
Indoor Air Quality Program
April 2008

Background/Introduction

At the request of the Holbrook Board of Selectmen and the Holbrook Board of Health (HBOH), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health (BEH) provided assistance and consultation regarding indoor air quality at each of Holbrook's public schools. These assessments were jointly coordinated through Kathleen Moriarty, Public Health Agent, HBOH and the Holbrook Public School Department (HPSD).

On March 4, 2008, a visit was made to the South Elementary School (SES), 719 South Franklin Street, Holbrook, Massachusetts by James Tobin, Environmental Analyst in BEH's Indoor Air Quality (IAQ) Program, to conduct an assessment. Mr. Tobin was accompanied by Julie Hamilton, School Principal, Paul Prisco, Maintenance, and Ms. Moriarty during the assessment. On March 13, 2008, Cory Holmes an Environmental Analyst in BEH's IAQ Program visited the school to conduct a perimeter/exterior inspection of the building, accompanied by Mr. Prisco.

The school was built in 1966 and contains 14 general classrooms, small rooms for specialized instruction, a gymnasium, kitchen, cafeteria, library and an art/music room. Windows are openable throughout the building.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. MDPH staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses approximately 360 students in grades 4 through 6, with approximately 25 staff members. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in 19 of 29 areas at the time of the assessment, indicating poor air exchange in the majority of the areas surveyed; mainly due to non-functional mechanical ventilation equipment. Rooftop exhaust ventilation motors were corroded with rust; belts were missing, wiring was damaged and electrical switches were broken. To provide air exchange the school employs an open window policy, requiring that at least one window in each classroom be open during the school day. It is important to note that several classrooms were empty/sparsely populated, which along with opened windows, can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy and with windows closed.

Fresh air is supplied to classrooms by unit ventilator (univent) systems (Picture 1). A univent draws air from the outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Univents were found obstructed by furniture, books and other materials. In order for univents to provide fresh air as designed, air diffusers, intakes and return vents must remain free of obstructions. Importantly, these units must remain "on" and be allowed to operate while rooms are occupied. Univents are also original 1960s era equipment, making them approximately 40+ years old. Efficient function of such equipment can be difficult to maintain since compatible replacement parts are often unavailable.

Exhaust ventilation in classrooms is provided by wall vents ducted to rooftop motors. As previously mentioned, exhaust ventilation was in disrepair at the time of the assessment. Exhaust vents are located in an area partitioned by panels that serve as the designated coat area (Picture 3). The panels are undercut to allow air to move freely; however, airflow under the panels is blocked by furniture (e.g. file cabinets, tables, etc.) and other stored materials (Pictures 4 and 5). A number of exhaust vents were also obstructed by coats, bags and stored materials (Pictures 6 through 8). As with univents, in order to function properly, exhaust vents must be activated and allowed to operate while rooms are occupied. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up leading to indoor air/comfort complaints.

Room 22 did not have a means of mechanical ventilation or windows. BEH staff recommended providing airflow or relocating the room. In subsequent correspondence, BEH staff learned that the school was investigating possible measures to provide air exchange.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The last balancing of these systems was at the time of the installation.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

Temperature measurements in the school during the assessment ranged from 71º F to 75º F, which were within the MDPH recommended comfort range in all areas surveyed (Table 1).

The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is often difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents/exhaust vents deactivated/obstructed).

The relative humidity measured in the building during the assessment ranged from 33 to 43 percent, which was within or close to the lower end of the MDPH recommended comfort range (Table 1). The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Plants were located in a number of classrooms. Plants, soil and drip pans can serve as sources of mold growth and should be properly maintained. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. In addition, flowering plants can be a source of pollen. Therefore, plants should be located away from univents to prevent aerosolization of mold, pollen and particulate matter.

Some classrooms were equipped with exterior doors. Several of these doors had damaged weather stripping, and light could be seen penetrating through the spaces underneath.

Spaces beneath exterior doors can serve as a source of drafts and moisture into the building, causing water damage and potentially leading to mold growth.

BEH staff examined the building to identify breaches in the building envelope that could provide a source of water penetration. Several potential sources were identified:

- Damaged/rotted woodwork and exterior doors (Pictures 9 and 10);
- Missing/damaged mortar and exterior brick (Pictures 11 through 13);
- Shrubbery/trees in close proximity to the building (Picture 14), which holds moisture against exterior brick and prevents drying;
- Missing/damaged joint compound (Pictures 15 and 16);
- Missing/damaged caulking around univent air intakes (Picture 17); and
- Missing/damaged caulking around window panes/frames (Pictures 18 through 20).

The aforementioned conditions represent potential water penetration sources. Over time, these conditions can undermine the integrity of the building envelope and provide a means of water entry into the building via capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001). In addition, these breaches may provide a means of egress for pests/rodents into the building.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed/discarded.

Lastly, water coolers were observed in some classrooms (Picture 21). It is important that the catch basin of a water cooler be cleaned regularly as stagnant water can be a source of odors, and materials (i.e., dust) collected in the water can provide a medium for mold growth. Water basins should be emptied and cleaned periodically to prevent growth and odors.

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems

(ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2006). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2006).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND.

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA established a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 27 μg/m^3 (Table 1). PM2.5 levels measured in the school ranged between 21 and 42 μg/m^3, which were slightly above the NAAQS PM2.5 level of 35 μg/m^3 in several areas surveyed (Table 1), and most likely due to deactivated mechanical ventilation equipment in combination with classroom activity. The areas where PM2.5 levels exceeded the NAAQS PM2.5 level of 35 μg/m^3 include: the gym, where a large class was playing floor hockey; the cafeteria, where the last lunch of the day was eating; and, classroom 13, where indoor recess was being held. In addition to providing air exchange, mechanical ventilation components provide removal of airborne particulates and continuous filtration of indoor air. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air concentrations of volatile organic compounds (VOCs) can be greatly impacted by the use of products containing VOCs. VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to identify materials that can potentially increase indoor VOC concentrations, BEH staff examined classrooms for products containing these respiratory irritants.

A work room near the main office contains several photocopiers. It is important that this area be equipped with local exhaust ventilation to help reduce excess heat and odors. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). As discussed rooftop exhaust vents were deactivated and in disrepair.

Multiple classrooms contained dry erase boards and related materials. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Cleaning products were found on countertops in a number of classrooms (Picture 22). Like dry erase materials, cleaning products contain VOCs and other chemicals. These chemicals can also be irritating to the eyes, nose and throat and should be kept out of reach of students.

Other conditions that can affect indoor air quality were observed during the assessment. In several classrooms, items were observed on the floor, windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation.

A number of exhaust/return vents, univent air diffusers and personal fans (Picture 23) were observed to have accumulated dust. As previously mentioned, exhaust vents were not functioning causing backdrafting into classrooms, which can aerosolize accumulated dust particles. Re-activated univents and fans can also aerosolize dust accumulated on vents/fan blades.

A number of classrooms had window-mounted air conditioners (ACs) or wall-mounted units (Picture 24). ACs are normally equipped with filters, which should be cleaned or changed as per manufacturer's instructions to avoid the build-up and re-aerosolization of dirt, dust and particulate matter.

An accumulation of chalk dust, pencil shavings and dry erase particulate was observed in several classrooms. When windows are opened and/or univents are operating, these materials can become airborne. Once aerosolized, they can act as irritants to the eyes and respiratory system.

One classroom contained a rabbit as a classroom pet. The rabbit cage contained wood shavings and accumulation of rabbit wastes. Porous materials (i.e., wood shavings) can absorb animal wastes and can be a reservoir for mold and bacterial growth. Animal dander, fur and wastes can all be sources of respiratory irritants. Animals and animal cages should be cleaned regularly to avoid the aerosolization of allergenic materials and/or odors.

Finally, in several classrooms, the sinks were being used as storage. Some sinks were covered with a piece of wood, while others simply had stored materials in the sink basin. The traps for the sink drains can dry out which can lead to sewer gas odors penetrating the room through unsealed traps. Sewer gas odors can be irritating to the eyes, nose, and throat.

Conclusions/Recommendations

Several issues regarding general building conditions, design and routine maintenance that can affect indoor air quality were observed during this IAQ assessment. The majority of issues listed in the report have been observed in other elementary school environments (clutter, dust control, building maintenance), particularly those built several decades ago. These factors can be associated with a range of IAQ related health and comfort complaints (e.g., eye, nose, and respiratory irritations).

The general building conditions, maintenance, work hygiene practices and the condition of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further degrade indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Operate both supply and exhaust ventilation continuously during periods of school occupancy, independent of classroom thermostat control to maximize air exchange.
2. Restore exhaust ventilation in classrooms and common areas (e.g., teacher's workroom); make repairs as necessary.
3. Remove all blockages from univents and exhaust vents to ensure adequate airflow (e.g., beneath wall panels Pictures 4-8). Remove coat hooks directly in front of exhaust vents. Consider reconfiguring the layout of some classrooms to facilitate airflow.
4. Ensure classroom doors are closed to maximize air exchange.

5. Continue to use openable windows in conjunction with mechanical ventilation to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
6. Continue to investigate possible measures to provide air exchange to room 22. Remediation plans should be approved by the Board of Health and/or the Building Inspector prior to commencement.
7. Consider adopting a balancing schedule of every 5 years for all mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).
8. Change filters for air-handling equipment (e.g., univents, AHUs and ACs) as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.
9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

10. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
11. Repair/replace damaged exterior doors and wood work.
12. Trim shrubbery/trees back approximately 5-feet to prevent water impingement on exterior brick.
13. Seal around windows/frames to prevent water penetration.
14. Seal around univent fresh air intakes to prevent water penetration.
15. Seal joints/spaces between exterior walls to prevent water penetration.
16. Seal open utility holes to prevent water penetration and block insect and rodent pathways into the building.
17. Store cleaning products properly and out of reach of students. Ensure spray bottles are properly labeled. *All* cleaning products used at the facility should be approved by the school department with MSDS' available at a central location.
18. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
19. Clean personal fans, univent air diffusers, return vents and exhaust vents periodically of accumulated dust.
20. Until exhaust system can be repaired/reactivated, temporarily seal exhaust vents with plastic and duct tape to prevent drafts and aerosolization of dust particles.
21. Clean chalk and dry erase trays to prevent accumulation of materials.

22. Clean and maintain aquariums and terrariums to prevent mold growth and associated odors.

23. Cap unused sinks or ensure water is poured into the drains every other day (or as needed) to maintain integrity of the traps.

24. Consider adopting the US EPA document, "Tools for Schools" to maintain a good indoor air quality environment on the building (US EPA, 2000). This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.

25. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://mass.gov/dph/indoor_air.

The following **long-term measures** should be considered:

1. Contact an HVAC engineering firm for an assessment of the ventilation system's control system (e.g., controls, air intake louvers, thermostats). Based on the age, physical deterioration and availability of parts for ventilation components, such an evaluation is necessary to determine the operability and feasibility of repairing/replacing the equipment.

2. Replacement/repair of window systems.

3. Re-pointing and waterproofing of exterior walls to prevent water intrusion. This measure should include a full building envelope evaluation.

References

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Picture 1

1960's Vintage Classroom Univent

Picture 2

Univent Fresh Air Intake

Picture 3

Undercut Panels Allowing Free Airflow to Exhaust Vent behind Panels

Picture 4

Airflow under Panels Blocked

Picture 5

Furniture Blocking Airflow to Exhaust Vent

Picture 6

Coats, Bags and Stored Materials Blocking Exhaust Vent

Picture 7

Stored Materials near Exhaust Vent

Picture 8

Stored Materials in Exhaust Area

Picture 9

Damaged Exterior Woodwork and Door

Picture 10

Close-Up of Damaged Exterior Woodwork and Door

Picture 11

Missing/Damaged Mortar/Exterior Brick

Picture 12

Missing/Damaged Mortar/Exterior Brick

Picture 13

Missing/Damaged Mortar/Exterior Brick

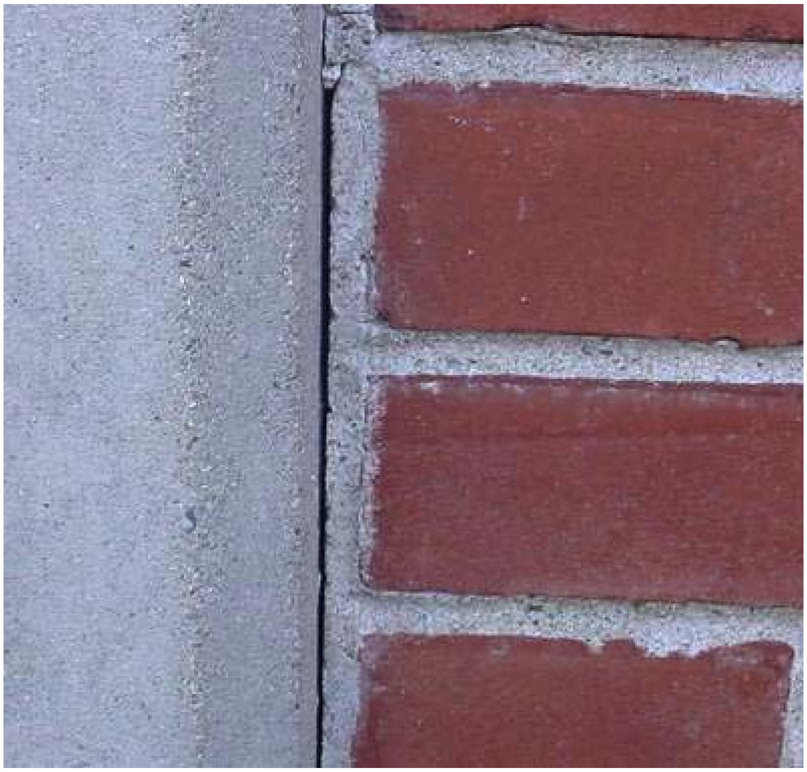
Picture 14

Trees/Shrubbery in Close Proximity to Exterior Brick

Picture 15

Missing/Damaged Sealant/Joint Compound between Exterior Walls

Picture 16



Missing/Damaged Sealant/Joint Compound between Exterior Walls

Picture 17

Missing/Damaged Caulking/Sealant around Univent Fresh Air Intakes

Picture 18

Missing/Damaged Caulking/Sealant around Window Panes

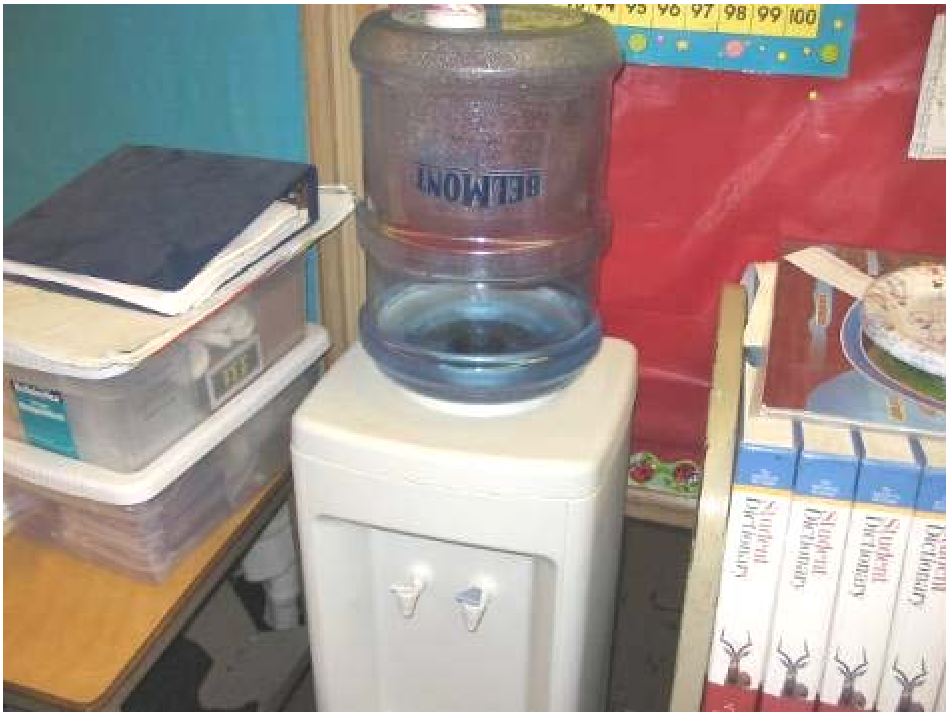
Picture 19

Missing/Damaged Caulking/Sealant around Window Panes

Picture 20

Missing/Damaged Caulking/Sealant around Window Frame

Picture 21



Water Cooler in Classroom

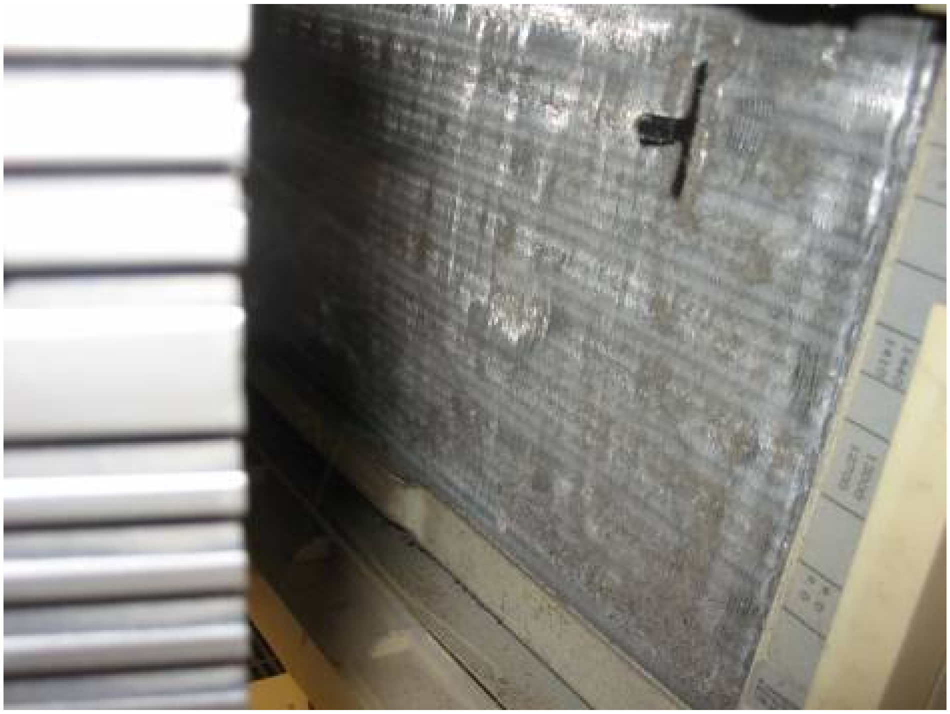
Picture 22

Spray Cleaners in Classroom

Picture 23

Exhaust Vent Blocked, Note Accumulated Dirt and Dust on Vent

Picture 24



Accumulated Dirt and Dust on AC Filter

Location: South School, Holbrook, MA
Address: 719 South Franklin Street

Indoor Air Results
Date: 03-04-2008

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
background		64	47	396	ND	27				Overcast
Atrium	0	73	38	878	ND	34	Y	N	N	Garden
Cafeteria	125	75	40	1255	ND	38	N	Y	Y	Exhaust off; Univent weak; Space underneath outside door; Cleaners
Guidance	1	73	38	458	ND	25	Y	Y	N	Univent blocked by furniture; Windows open; AC; DEM
Gym	27	73	41	1369	ND	42	N	Y	Y	Exhaust off; Univent off/weak
Main Office	2	74	38	565	ND	29	Y	N	N	AC; PC; DO
Nurse	2	73	40	554	ND	32	Y	N	Y	Windows open; AC; DO
Teacher's Room	6	73	40	836	ND	39	Y	Y	Y	Exhaust off; Cleaners; Bubbler; Laminator
Work Room	0	74	39	598	ND	31	N	N	Y	Exhaust off, dusty; 2 PCs

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect

AD = air deodorizer
AC = air conditioner
BD = backdraft
CD = chalk dust

CT = ceiling tile
DEM = dry erase materials
DO = door open

PC = photocopier
PF = personal fan
PS = pencil shavings

TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WD = water-damaged

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%
Particle matter 2.5 < 35 ug/m^3

Location: South School, Holbrook, MA **Indoor Air Results**

Address: 719 South Franklin Street **Date: 03-04-2008**

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
1	30	72	41	1011	ND	30	Y	Y	Y	Exhaust blocked; Univent blocked by furniture; Partition blocked furniture; Sink as storage; Windows open; DEM
2	31	73	43	1272	ND	31	Y	Y	Y	Exhaust off, blocked; Univent blocked by furniture; Windows open; Partition blocked by furniture; Bubbler; Clutter; WD ceiling; DEM
3	29	73	42	989	ND	28	Y	Y	Y	Exhaust off, blocked; Partition blocked; Windows open; Sink as storage; Cleaners; Clutter; Window Screens damaged/missing; CD; DEM
4	6	74	39	1025	ND	21	Y	Y	Y	Exhaust off, blocked; Windows open; Partition blocked by stored materials; Spray cleaners; DEM
5	1	74	41	909	ND	26	Y	Y	Y	Exhaust off, blocked; Windows open; 30 occupants gone 2 mins; Dust on flat surfaces; DEM; PF
6 Library	0	72	39	462	ND	23	Y	Y	Y	Windows open; Partition blocked by stored materials; Cleaners

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect
AD = air deodorizer
AC = air conditioner
BD = backdraft
CD = chalk dust
CT = ceiling tile
DEM = dry erase materials
DO = door open
PC = photocopier
PF = personal fan
PS = pencil shavings
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WD = water-damaged

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m^3

Location: South School, Holbrook, MA | **Indoor Air Results**

Address: 719 South Franklin Street | **Date: 03-04-2008**

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
7	31	75	40	1389	ND	28	Y	Y	Y	Exhaust BD, blocked by coats and bags; Windows open; Sink as storage; Cleaners; Clutter
8 Computer Lab	0	74	41	1031	ND	27	Y	Y	Y	Exhaust off, BD, dusty; Windows open; Partition blocked by stored materials; AC-dirty; 30 computers and server; Filter stored away
9	32	74	39	668	ND	29	Y	Y	Y	Exhaust off, blocked by coats; Windows open; DEM; DO
10	8	71	40	502	ND	27	Y	Y	Y	Exhaust off; Windows open; Plants; Clutter; DEM; DO
11	24	73	39	567	ND	29	Y	Y	Y	Exhaust off, blocked by coats; Partition blocked; Windows open; Cleaners; DEM; DO
12	28	73	43	1113	ND	29	Y	Y	Y	Exhaust off, blocked; Windows open; DEM
13	29	73	40	882	ND	39	Y	Y	Y	Exhaust off; Windows open; Plants hanging over univent; Stored materials in partitioned area; Cleaners; DEM; PF
14	30	72	42	1029	ND	33	Y	Y	Y	Exhaust off, blocked; Windows open

ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
ND = non detect
AD = air deodorizer
AC = air conditioner
BD = backdraft
CD = chalk dust
CT = ceiling tile
DEM = dry erase materials
DO = door open
PC = photocopier
PF = personal fan
PS = pencil shavings
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WD = water-damaged

Comfort Guidelines

Carbon Dioxide:	< 600 ppm = preferred	Temperature:	70 - 78 °F
	600 - 800 ppm = acceptable	Relative Humidity:	40 - 60%
	> 800 ppm = indicative of ventilation problems	Particle matter 2.5	< 35 ug/m^3

Location: South School, Holbrook, MA

Address: 719 South Franklin Street

Indoor Air Results

Date: 03-04-2008

Table 1 (continued)

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	PM2.5 ($\mu g/m^3$)	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
15	3	72	39	497	ND	27	Y	Y	Y	Exhaust off; Windows open; Space underneath outside door; Cleaners; DEM
16 Art	28	72	41	988	ND	30	Y	Y	Y	Univent blocked; Windows open; DEM
17	20	74	43	1245	ND	36	Y	Y	Y	Exhaust off; Univent blocked by furniture; Windows open; Rabbit in cage; Clutter; AD; DEM
19	20	71	42	902	ND	28	Y	Y	Y	Exhaust off, blocked by coats and bags; Windows open; Dust on blinds
20	0	72	33	852	ND	21	N			Passive airflow, Open ceiling; CF; DEM
21	0	73	35	774	ND	26	N			Passive airflow, Open ceiling; DEM
22	1	74	40	1094	ND	27	N	N	N	DEM; Server

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								Supply	Exhaust	
Exterior/ Perimeter										Missing/damaged mortar-exterior brick Missing/damaged sealant/joint compound between ext walls Missing/damaged sealant/caulking around univent air intakes Missing/damaged sealant/caulking around window panes/frames Trees/shrubbery in close contact with exterior brick

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Carbon Dioxide:	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems	Temperature: Relative Humidity: Particle matter 2.5	70 - 78 °F 40 - 60% < 35 ug/m^3